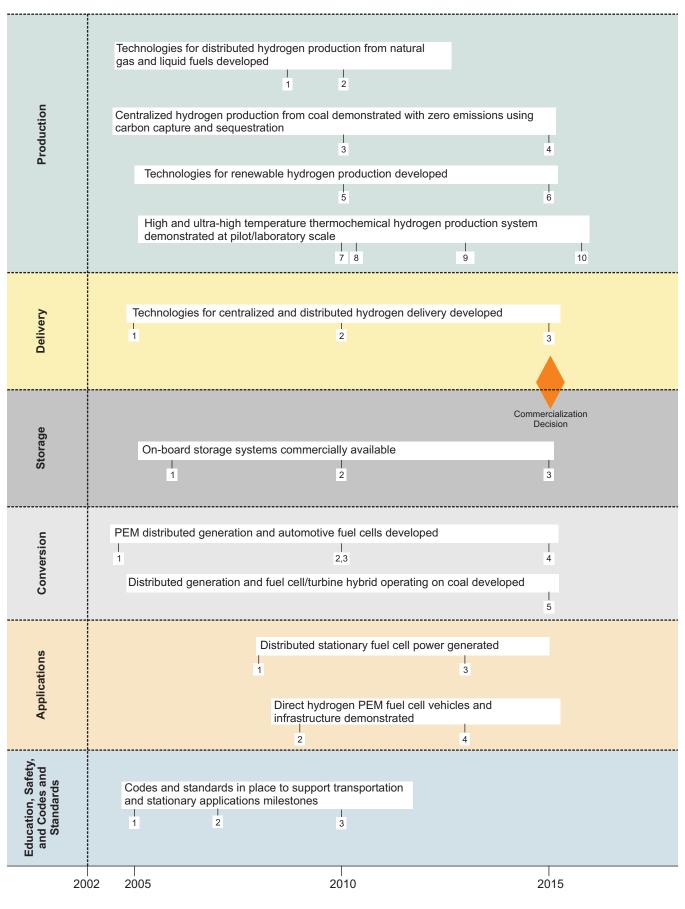
FIGURE 8. TECHNOLOGY DEVELOPMENT TIMELINE (PHASE I): MILESTONES AND DECISION POINTS



Production Milestones

Distributed Natural Gas/ Liquid Fuels*

- 2009: Develop technology to produce distributed hydrogen from natural gas or liquid fuels at a refueling station that projects to a cost of \$2.50/gge for hydrogen. [At the pump, untaxed, no carbon sequestration]
- 2010: Develop technology to produce hydrogen from natural gas or liquid fuels at a refueling station that projects to a cost of \$1.50/gge for hydrogen. [At the pump, untaxed, no carbon sequestration, at 5000 psig]

Central Coal*

- 2010: Develop pilot scale membrane separation and reactive/membrane separation technology for hydrogen production that meets cost targets.
- 4. 2015: Demonstrate a zero emission coal plant producing hydrogen and power with carbon capture and sequestration at a 25% cost reduction that projects to \$0.80/gge at the plant gate (\$1.80/gge delivered).

Renewable Resources

- 2010: Develop technologies for integrated wind hydrogen production at \$2.85/gge delivered assuming a 500 gge/day electrolyzer system and \$0.04/kWh wind electricity (2015: \$2.25/gge).
- 6. 2015: Demonstrate laboratory-scale biological system to produce hydrogen at a cost that projects to \$10/gge at the plant gate (\$11/gge delivered). Demonstrate laboratory-scale photoelectrochemical water splitting at a cost that projects to \$5/gge at the plant gate (\$6/gge delivered). The long term goal for these hydrogen production technologies is to be competitive with gasoline.

High-Temperature Thermochemical

- 2010: Laboratory-scale demonstration of ultra-hightemperature thermochemical hydrogen production from solar reactors that project to a cost of \$2.50/gge (\$3.80/gge delivered).
- 2011: Pilot-scale demonstration of high-temperature thermochemical production for use with nuclear reactors that projects to a cost of \$2.50/gge (\$3.50/gge delivered).
- 9. 2013: Design of engineering scale nuclear hydrogen production system completed.
- 2017: Engineering-scale demonstration of thermochemical hydrogen production system with cost that projects to less than \$2.00/gge at the plant gate (\$3/gge delivered) using heat from nuclear reactors.

Storage Milestones

- 1. 2006: Downselect hydrogen storage options with potential to meet 2010 targets.
- 2010: Develop and verify on-board storage systems achieving: 6% by weight capacity and 1500 watt hours/ liter energy density at a cost of \$4.00/kWh of stored energy.
- 3. 2015: Develop and verify on-board storage systems achieving: 9% by weight capacity, 2700 watt hours/ liter, and \$2.00/kWh.

Applications Milestones

- 2008: Validate first regional networks with fuel cell systems that project a cost of less than \$1,250/kW.
- 2009: Direct hydrogen polymer electrolyte membrane fuel cell vehicles demonstrated at multiple sites, achieving 2,000 hours durability.
- 2013: Validate stationary fuel cell system that co-produces hydrogen and electricity at 40,000 hours durability with 40% efficiency at a cost of \$750/kW or less.
- 2013: Validate direct hydrogen polymer electrolyte membrane fuel cell vehicles achieving 5,000 hours durability (service life of vehicle) and 300 mile range.

Pha Dec

Phase 1 Commercialization Decision: 2015

Based on technology development success in meeting customer requirements and establishing a business case.

Conversion Milestones

- 2004: On-board fuel processing Go/No Go decision based on ability to achieve 78% efficiency and <0.5 minute start time.
- 2010: Distributed stationary generation natural gas/ propane 50-250 kW fuel cell developed: 40% electrical efficiency, 40,000 hours durability (equivalent to service life between major overhauls), at a cost of less than \$400-\$750/kW.
- 2010: Develop direct hydrogen polymer electrolyte membrane automotive fuel cell operating at 60% peak efficiency, 220 W/L density, 325 W/gge specific power at a cost of \$45/kW (automotive production quantity).
- 2015: Polymer electrolyte membrane automotive fuel cell meets cost of \$30/kW.
- 2015: Fuel cell/turbine hybrid operating on coal developed at a cost of \$400/kW with a system efficiency of 70% with carbon sequestration.

Education, Safety, and Codes and Standards Milestones

- 2005: Publish codes and standards models and safety and training materials.
- 2. 2007: Education program on safety in place.
- 2010: Technical codes and standards in place to support regulatory standards.

Delivery Milestones

- 2005: Define a cost-effective hydrogen fuel delivery infrastructure for supporting the introduction and long-term use of hydrogen for transportation and stationary power.
- 2. 2010: Develop technologies to reduce the cost of hydrogen fuel delivery from the point of production to the point of use in vehicles or stationary power units to <\$1.30/gge of hydrogen.
- 3. 2015: Develop technologies to reduce the cost of hydrogen fuel delivery from the point of production to the point of use in vehicles or stationary power units to <\$1.00/gge of hydrogen.
- * The assumed feedstock cost for natural gas is \$4.00/million Btu and the assumed cost for coal is \$29.00/short ton.